Amendments to the Drawings:

The proposed drawing corrections filed on September 11, 2003 have been approved. Applicant herewith submits replacement drawing sheets in accordance with the required format.

Attachment: Replacement Sheets

Remarks

Applicant respectfully requests that Examiner consider the Application in view of the amendments above and the remarks below.

Disposition of Claims

Claims 1-3, 5-6, 18 and 20-23 are rejected. Claims 4, 7-17 and 19 have been withdrawn but not canceled. Claims 1-23 remain pending.

Rejections under 35 U.S.C. §102

Applicant understands its obligation under 37 CFR 1.56.

Claims 18, 20, 22 and 23 are rejected under 35 USC 103(a) as being unpatentable over Stultz et al (US 6,246,711). Specifically Claim 18 is rejected because "Stultz et al. teach in Column 2, lines 14-16 a resonant pumped erbium laser and further teach in Column 2, lines 62-63 an erbium concentration of 0.5%, which is about 1.0%."

Applicant respectfully traverses this rejection. As is described below in detail, Stultz et al. do not teach a <u>resonant pumped</u> erbium laser. An eyesafe erbium laser refers to one where the laser emission is from the first excited state ($^4I_{13/2}$) to the ground state ($^4I_{15/2}$). In general, this emission is found to be between 1.53 and 1.65microns, and is primarily driven by the host composition (i.e., silica glass, phosphate glass, YAG crystal, YLF crystal, etc.). Until recently, there was no efficient way of exciting the upper laser state ($^4I_{13/2}$). Figure 1 shows how it was most commonly done, which is the type of laser system described by Stultz et al. A sensitizing agent, most commonly trivalent ytterbium (Yb^{3+}) is the direct absorber of pump radiation. It is usually heavily doped into the host matrix to insure efficient pump absorption. The wavelength for pumping Yb^{3+} is usually between 940 and 980nm. The excited Yb^{3+} ions transfer energy by a radiationless process by exciting nearby trivalent erbium (Er^{3+}) ions into the $^4I_{11/2}$ level. These quickly decay into the $^4I_{13/2}$ level. The Er concentration is kept relatively low (0.5% concentration) to optimize the transfer of energy from Yb to Er, and not the reverse process. Again, an example of this type of laser system is described by Stultz et al.

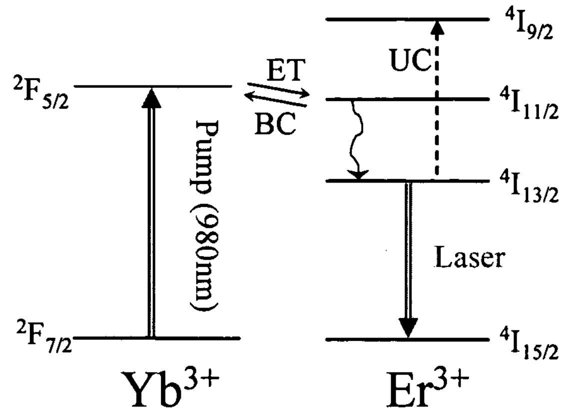

Figure 1. Traditional erbium excitation scenario using a Yb-sensitizer

There are some serious limitations to this architecture for eyesafe ($^4I_{13/2} \Rightarrow {}^4I_{15/2}$) laser extraction. First, the radiationless transition from the $^4I_{11/2}$ level to the $^4I_{13/2}$ level results in waste heat, and this makes high average power operation (with multi-Watt output) very difficult. Another way of looking at this is considering the "quantum efficiency" of the system. At best, each pump photon will create one eyesafe laser photon, and the theoretical maximum efficiency is the ratio of photon energies ($\lambda_{Pump}/\lambda_{Laser} \sim 0.98/1.6 \sim 62\%$). The 40% of the pump power that doesn't result in laser action is primarily waste heat.

Another, more significant limitation is that of energy storage. The populations of the Yb and Er ions reach an equilibrium condition, in which only a small fraction of Er ions are populated. The vast majority of energy stored in the laser medium is held by the Yb ions. When one tries to rapidly extract the stored energy (by Q-switching), only the eyesafe energy held by the Er ions can be realized. This problem is well known to those skilled in the art of sensitized laser systems. Hence, not only are Yb-sensitized eyesafe erbium lasers poor high average power sources, they are inefficient Q-switched lasers.

In contrast, the present application describes means of mitigating the above mentioned problems that are significantly different than previous technologies. Key among them is the use of <u>resonant pumping</u>. Resonant pumping refers to direct excitation of the upper laser state ($^4I_{13/2}$ in this case). Figure 2 shows this scenario. A pump laser of appropriate wavelength directly excites the upper laser level, and no energy transfer process is required (though parasitic upconversion can still occur out of the $^4I_{13/2}$ level). The elimination of the sensitizing Yb ions

provides two significant benefits. First, the elimination of the radiationless energy transfer from the $^4I_{11/2}$ to $^4I_{13/2}$ state eliminates a large amount of waste heat. The second great advantage of this approach is that all of the absorbed pump energy is stored by the Er ions, therefore all of it is available for Q-switched extraction, making this an efficient high-energy eyesafe laser system.

The primary difficulty with operating the eyesafe erbium laser transition without a sensitizer is pump efficiency. The present application describes one embodiment using dilute (<2%) Er concentrations to minimize the effects of upconversion (a parasitic loss mechanism to upper lying Er levels, driven primarily by the concentration (i.e., physical proximity) of the excited Er ions). The peak absorption coefficient to the $^4I_{13/2}$ level from the ground state is relatively low (~$0.85cm^{-1}$ at 0.5% doping level), so long crystals are required to efficiently absorb the pump (L = 4 – 6cm). Figure 3 shows the absorption spectrum of Er-doped YAG, one embodiment of this invention. Strong absorption features occur at ~1532nm, ideal for excitation with an Er fiber laser, or an erbium glass laser (both of these are of the traditional Yb-sensitized Er laser architecture). Absorption features near 1470nm can be excited with laser diodes. It is only with recent developments in 1470nm diode lasers and 1530nm fiber lasers that the resonantly pumped eyesafe Er lasers (capable of high average power and high energy storage) could be developed.

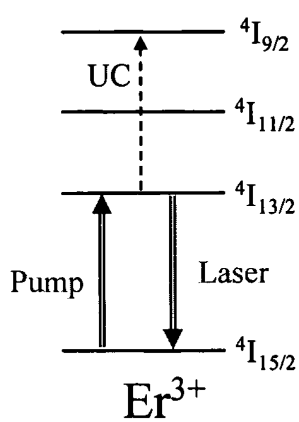

Figure 2. New erbium excitation scenario without Yb-sensitizer. This permits high power / high energy operation, enabled by newly available pump sources.

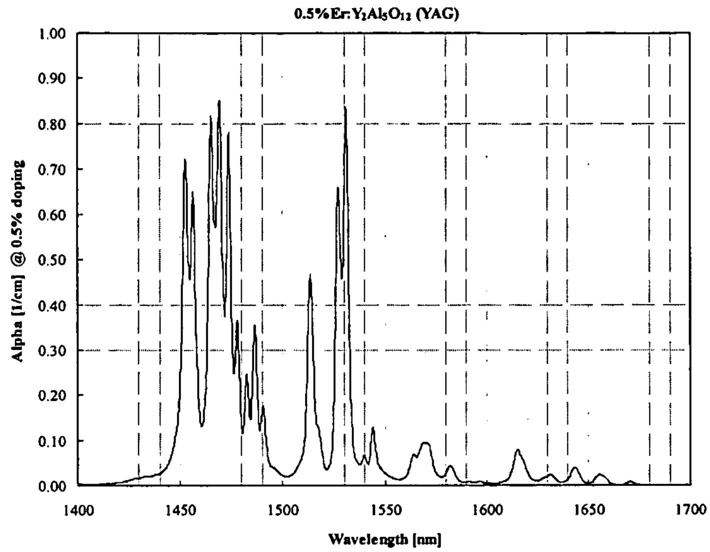

Figure 3. Example of erbium $^4I_{13/2}$ absorption spectrum (Er:YAG) showing peak absorption features near 1532nm (fiber laser pumping) and 1470nm (direct diode pumping).

In summary, the present application, unlike Stultz et al., has solved the problems typically associated with eyesafe Er lasers (high heat load, poor energy storage, poor absorption efficiency) by resonant pumping *of the first excited state*, which allows the elimination of the sensitizers, and by reducing upconversion losses with dilute Er concentrations.

Applicant respectfully traverses the rejection of Claims 20, 22 and 23, which are dependent on Claim 18, as claims dependent on an allowable independent claim are also allowable.

Rejections under 35 U.S.C. §103

Claims 1-3, 5 and 6 are rejected under 35 USC 103(a) as being unpatentable over Kokubu (U.S. 6,179,830) in view of Stultz et al. Specifically, Claim 1 is rejected because:

> "Kokubu further teaches in Column 11 that said laser (13) may be a resonant erbium laser..." (p. 4)

Applicant respectfully traverses this rejection. Kokubu does make reference to the use of an eyesafe erbium laser in a medical application, but Kokubu does not make any reference to, or suggest in any way, a resonant pumped eyesafe erbium laser. (See above discussion on differences between conventional eyesafe erbium lasers and resonant pumped eyesafe erbium lasers.) Moreover, Stultz et al, as is discussed above in detail, also describes a conventional

eyesafe erbium laser. Neither of these references describes the resonant pumping described in the present Application.

Applicant respectfully traverses the rejection of Claims 2-3, 5 and 6, which are dependent on Claim 1, as claims dependent on an allowable independent claim are also allowable.

Claim 21 is rejected under 35 USC 103(a) as being unpatentable over Stultz et al. in view of Kokubu. Applicant respectfully traverses the rejection of Claim 21, which is dependent on Claim 18, as claims dependent on an allowable independent claim are also allowable.

Conclusion

Applicant believes that this paper is responsive to the grounds of rejection cited by the Examiner in the Office Action dated December 11, 2003, and respectfully requests favorable action on the Application. Examiner is invited to telephone the undersigned, applicant's attorney of record, to facilitate advancement of the Application.

The applicant herewith petitions the Commissioner of Patents and Trademarks to extend the time for reply to the Office action dated December 11, 2003 for two months. Please charge deposit account number 190130 (Reference Number D4465), in the amount of $420.00 to cover the cost of the extension. Any deficiency or overpayment should be charged or credited to the above numbered deposit account.

Respectfully submitted,

Date: 05.11.04

By: [signature]

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